

Prototype Measurement of Active Reflectarray Antenna using a Diode Grid in the W-band

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Abstract - This paper reports the antenna measurement results of a new active reflectarray antenna using a diode grid in the W-band. The reflectarray antenna consists mainly of a diode grid, which forms and steers the beam by controlling the bias applied to the diodes. The prototype antenna measurement confirmed that the proposed reflectarray with the diode grid shapes the beam by switching the diodes state as designed. This result implies that the antenna concept of diode state switching may be able to control the antenna beam pattern and the orientation electronically.

Index Terms — Active Reflectarray Antennas, Diode Grid, Antenna Beam Control, Lens Antenna.

1. Introduction

Since the Concorde accident in 2000, the threat of FOD (Foreign Objects and Debris) is focused on the safety issues in the airport. According to the Report [1], this accident was caused by a thin metallic strip on the runway. ENRI have been studying a millimeter-wave radar system as the FOD sensor to find such thin obstacles [2-6]. For the radar system, electrical beam steering is an attractive solution to decrease the maintenance cost and to increase the data rate of the radar images. There are some techniques to steer the beam electrically [7, 8] and several authors have been trying to establish new structures for fast beam scanning with active reflectarray antenna technique [9-12].

This paper proposes an active reflectarray antenna using a diode grid. Generally, reflectarray antenna focuses the beam by passive patches on the array surface which correct the incident wave phase. However, in the active reflectarray case, the diode grid works instead of the patches and the phase shift changes depending on the applied bias to the diode.

The purpose of this paper is to confirm our proposed reflectarray antenna concept, that is a switched diode grid on the reflectarray shapes the antenna beam pattern. Following chapters describe the reflectarray concept, the prototype antenna measurement, and the change in the measured antenna beam pattern by the diode state control.

2. Reflectarray antenna using diode grid

Fig. 1 shows the electrical beam steering concept of the reflectarray antenna. The antenna consists of a W-band primary source, an electrical controlled reflectarray and a dielectric lens. The primary source illuminates the entire

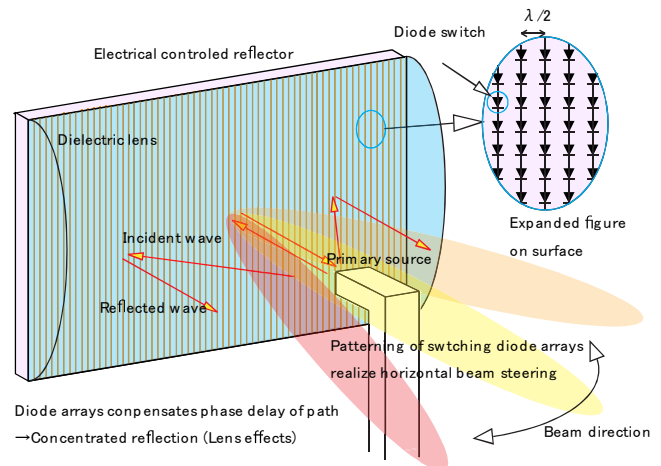


Fig. 1. Concept of the active reflectarray with diode grid.

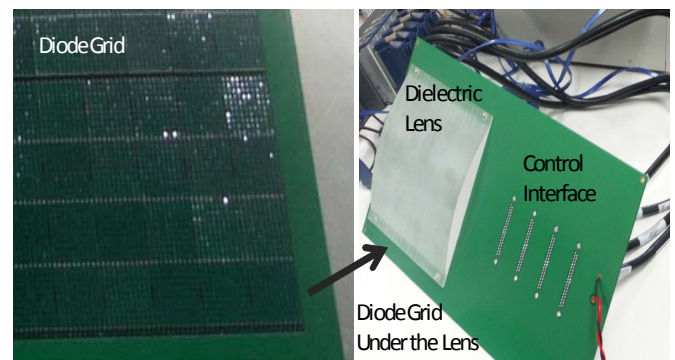


Fig. 2. Prototype diode grid and entire reflectarray.

reflector. Electrical controlled reflectarray has a diode grid whose separation width is about a half wavelength as shown in the magnified figure. Ideally the diode grid shapes the beam in two (azimuth and elevation) dimensions. However, the diode grid is aligned only in the azimuth direction to simplify the study, and the dielectric lens shapes the beam in elevation. The diode grid is designed to invert the phase of the reflected wave by switching the diode states. The 180 degree phase shift by switching realizes a one bit Fresnel zone pattern on the reflectarray surface [10]. This paper describes the prototype reflectarray antenna and the antenna pattern evaluation at each diode state.

Fig. 2 (left photo) shows the prototype diode grid. The GaAs Flip Chip PIN diodes (M/A COM, MA4GP907) are mounted along microstrip lines on a substrate (Dielad 880, $\epsilon_r = 2.2$ at 10 GHz). The microstrip line width is 0.3 mm, the interval is 1.3mm, and the diode spacing is 1.5mm. The substrate is 0.762 mm thick, and has a ground plane on the back. The CST unit cell simulation defined these parameters [12].

Fig. 2 (right photo) shows the prototype reflectarray. The Rexolite dielectric lens ($\epsilon_r = 2.53$, $n = 1.59$ at 10 GHz) covers the 80 x 120 diode grid. Entire dimensions of the diode grid are 120 mm x 156 mm, the focal length is 150 mm from the substrate surface, and the open-ended WR-10 rectangular waveguide is used as the primary source. The control circuit controls the diode state, by applying a forward bias or not applying a bias to each microstrip line. In short, the diode states on the same microstrip line are identical. Note that biased diode in this paper means applying forward bias.

3. Antenna Patterns at every diode state

The antenna azimuth patterns of the prototype reflectarray (Fig. 2. right) are measured in an anechoic chamber. The pattern measurements are in the following three diode grid's states, a) all diodes are biased, b) all diodes are NOT biased, c) diodes only on selected microstrip lines are biased. Only the case of c), the reflectarray surface is equivalent to a Fresnel reflector, may form the beam.

As can be seen from measured antenna patterns in Fig. 3, the prototype reflectarray forms the beam only when the partial selected diode lines are biased. This result means that the prototype antenna functions as expected in the proposed concept, thus switching the diode state enables to control the antenna beam. However, the antenna gain in the state c) is about 23 dBi and the aperture efficiency is 1%. Probably it is due to the loss in the biased diodes, they do not have fine reflection characteristics like passive patches. It is also explained from the gain difference between the case a) and b) in Fig. 3, that logically might be the same.

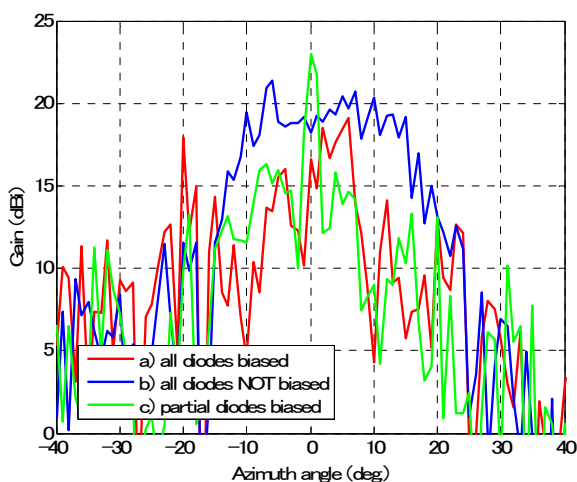


Fig. 3. Measured antenna pattern of the reflectarray.

4. Conclusions

This paper introduced a new concept of the reflectarray antenna using a diode grid. The diode grid inverts the reflection phase only when the selected diodes are biased to compose an equivalent Fresnel reflector.

In conclusion, the antenna pattern measurement of the prototype reflectarray with an 80 x 120 diode grid showed that the switched diode grid shapes the beam. This result means that the diode state switching can control the antenna beam pattern and the orientation.

As a future study, the diode control scheme needs to be ameliorated to realize the beam steering function of the reflectarray. Also we need to improve the antenna aperture efficiency.

Acknowledgment

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